Final Project Report – 31 January 2012

A Web-Based Tool to Measure Environmental Quality Standards for Phosphorus in Water at Lake Erie

Funded by Illinois-Indiana Sea Grant Program
Acushla Antony, Purdue University
West Lafayette, IN

The objective of this project was to enhance the NAPRA online web-based decision support tool to assess the impact of phosphorous losses on shallow ground water and surface water at farm and county levels with SSURGO soil data. A further objective was to determine impacts of current and future agricultural management practices common near the Great Lakes on phosphorus loads. Specifically, the tasks involved were: a) Enhance the NAPRA online web-based decision support tool and update the soil database using SSURGO soils suitable for field and county level evaluation. b) Assess the level of phosphorus reaching water with existing cropping management systems and assess the change in phosphorus level due to increases in biofeedstock production and intensive livestock production.

__Enhance the NAPRA online web-based decision support tool and update the soil database using SSURGO soils suitable for field and county level evaluation__.

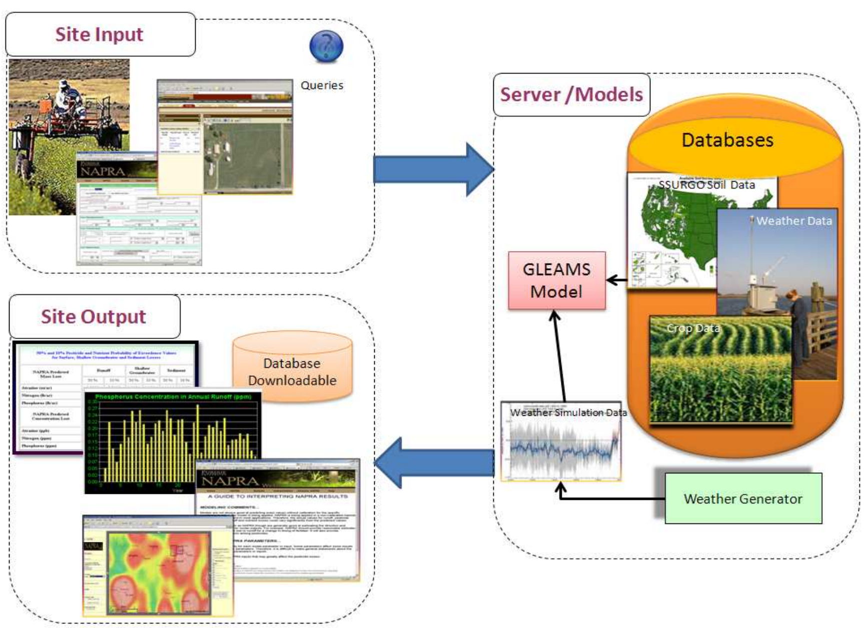

Figure 1. Conceptual schema of NAPRA Web tool

Web-based Mapping System

The designed web site "NAPRA Web" contains three main components (Figure 1): the first component serves as the Input Interface to the model using maps and tabular input; the second component consists of the model that does the analysis and the databases that are stored on the server; and the third component would include different tabular and graphical outputs from the model and a color gradient map to show the level of impact of pesticides and nutrients. A schematic description of the application architecture is shown in Figure 2. The enhancements incorporated in the model as described in the sections that follow.

Site Input

The input interface was modified to incorporate additional features. The basic input to the site is the cropping information and pesticide and nutrient management information. Soil type and location of a field can be submitted by the user in tabular form (figure 2) and the location of the farm through the Web Soil Survey for SSURGO.

Enhanced additional input parameters

SSURGO Parameters:

The user is directed to the web soil survey to select the area of interest from the SSURGO soil database**.** The original NAPRA WWW system simulated the effects of different agricultural management on hydrology, erosion, pesticides and nutrient for the farm level using the STATSGO database, but STATSGO soil data were not designed for farm level use. The SSURGO soil database is designed for farm level use, so it would be more accurate in its data than the STATSGO soil database at this scale. For larger areas, STATSGO would be much more suitable and less time consuming than using SSURGO. The online web soil survey is an effective tool that is used to retrieve current SSURGO soil data by specifying the area of interest. This tool facilitates users with selecting the area of interest and downloading the ESRI shape file and ASCII tabular data to the model. The Web Soil Survey tool is more beneficial than the SSURGO backup database as the database would require timely updating. In the Web Soil Survey (http://websoilsurvey.nrcs.usda.gov), the users digitize their field (figure 3) and the soil details entered into the model (figure 4).

*BMP Parameters**:***

The NAPRA Web tool can estimate the impacts of agricultural management systems on surface and subsurface hydrology and water quality, and help identify location-specific environmentally friendly agricultural management practices which are location specific. NAPRA Web does not readily allow simulation of structural BMPs; however, its engine GLEAMS is capable of simulating structural BMP's like filter strips, residue management, and contour farming. These BMPs are being included. The BMPs incorporated are buffer width and contour farming. Buffer width options are 0, 5m, and 15m. To incorporate contour farming, the CN was reduced by 3 and the USLE P factor modified based on the slope.

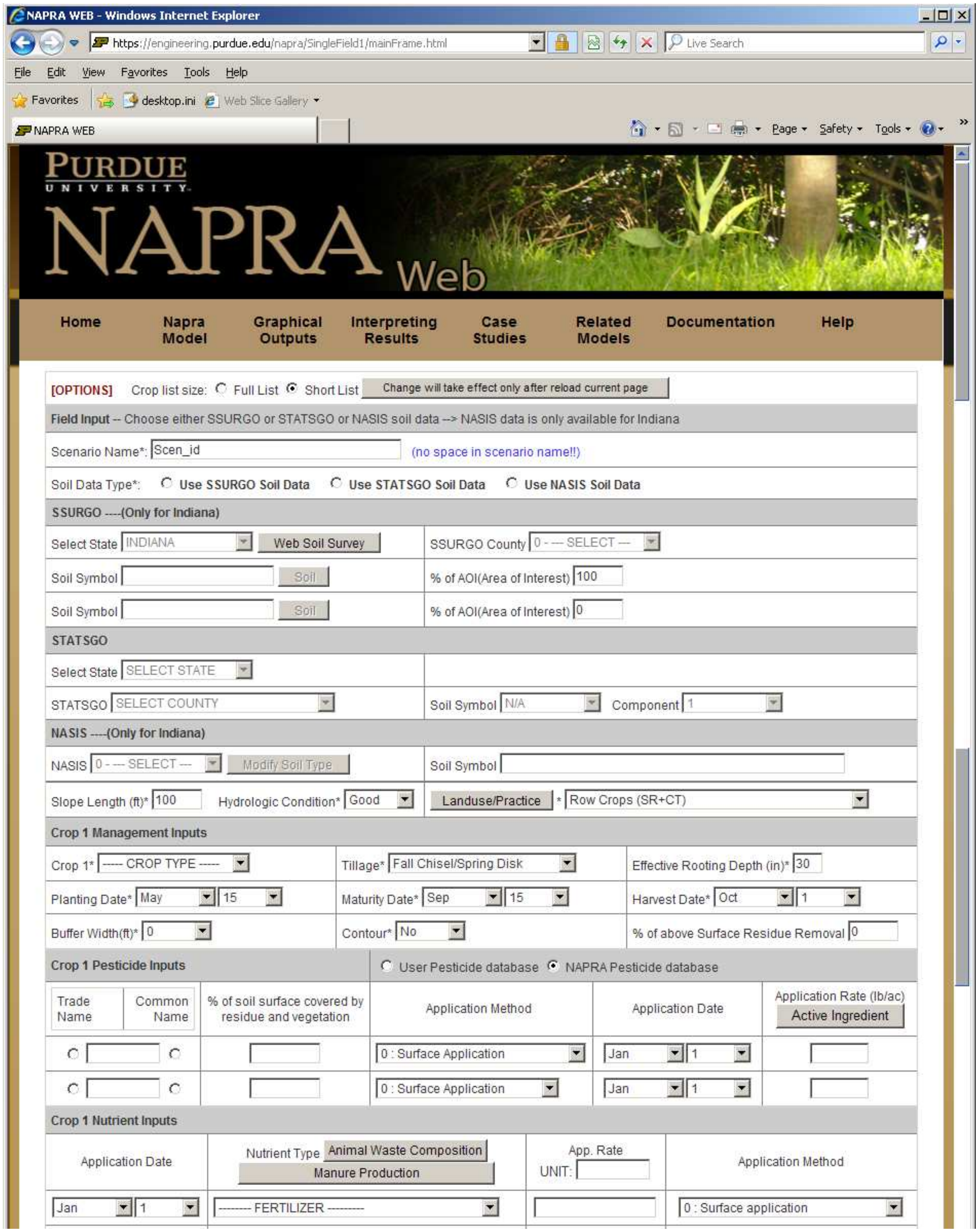

Figure 2. NAPRA Web Input Form

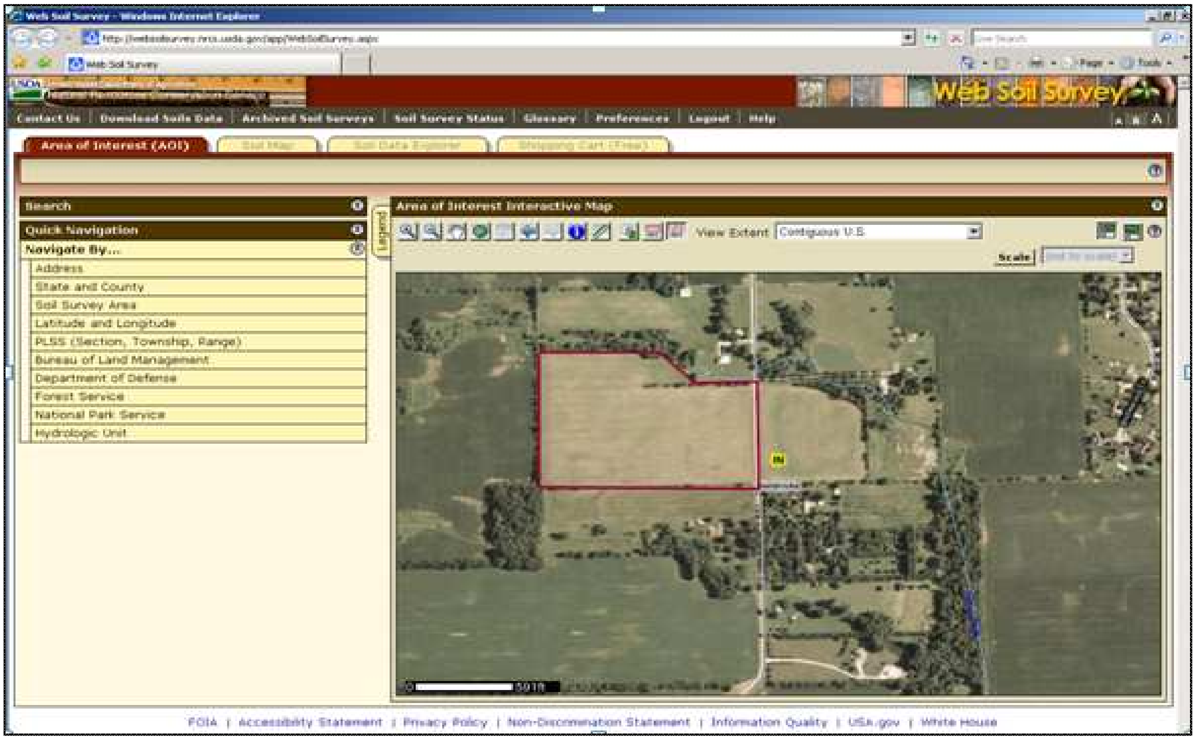

Figure 3. Web Soil Survey (Digitization of the Field)

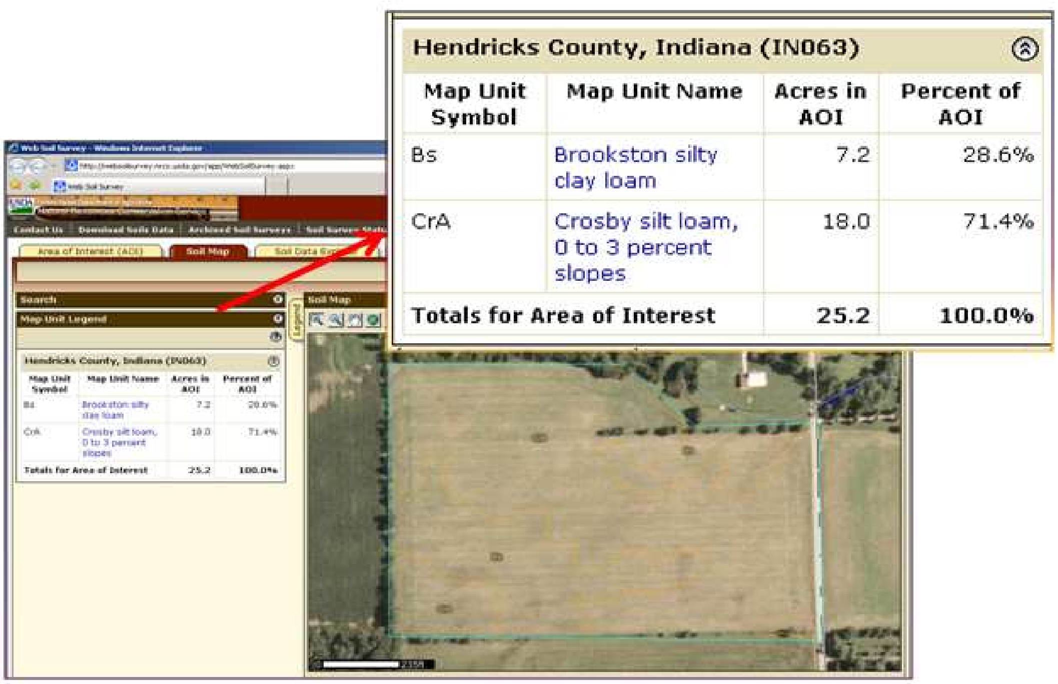

Figure 4. Web Soil Survey (Soil Map)

Biofeedstock parameters

Corn-stover is considered one of the best-suited biofeedstocks for bioenergy production based on regional transportation and economic analyses. Due do the current focus on the biofeedstock production, there is a need to quantify the environmental effects due to pollutant increase in biofeedstock production. The environmental effect due to pollutant load increase in biofeedstock production could be measured using the NAPRA model to identify management to help lessen the potential negative impacts of biofuel production. Three corn stover removal scenarios were incorporated in the NAPRA Web tool: baling a windrow (38%); raking and baling (52.5%); and shredding, raking and baling (70%). Surface residue was modified in the Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) model to reflect pre-defined yearly crop residue removal levels which allows appropriate amount of dry matter to be taken out of the system at harvest. Erosion is estimated using the modified Universal Soil Loss Equation (USLE) within GLEAMS. The Revised Universal Soil Loss Equation (RUSLE 2) was used to generate C factor values based on the crop, management and tillage data for use in GLEAMS.

Testing of hypothesis*: *There exists a spatial resolution beyond which both STATSGO and SSURGO would predict similar water quality response

A modeling framework was used to evaluate the influence of spatial resolution on the GLEAMS hydrological model to calculate the pollutant load at the edge of the field. The environmental risk analysis tool, Web NAPRA, is used to simulate long-term (32-years) runoff, percolation, nitrate-N, total phosphorus and atrazine (1-chloro-3-ethylamino-5-isopropylamino-2,4,6-atriazine) annual losses to the edge of each field in two watersheds for the two soil databases, SSURGO and STATSGO. In order to minimize the impact of variability on hydrologic/water quality output, the model was run with common inputs except variability of the soil inputs. The following management file was used for the simulations (table 1).

Table 1. NAPRA Web management inputs for corn and soybean production

Description	Corn Input	Soybean Input
Planting date	May 6	May 24
Harvest date	October 14	October 7
Maturity date	September 15	September 10
Tillage	Fall Chisel/ Spring Disk	No-till
Root zone depth	91.44 cm (36inches)	91.44 cm
Slope Length	30 m	30 m
% of soil cover	0	30 %
Fertilizer		
Nitrogen Fertilizer type	Anhydrous Ammonia (injected)	
Application Date	April 22	
Phosphorus Fertilizer type	Triple superphosphate (incorporated)	Triple superphosphate (incorporated)
Phosphorus Application Date	April 24	May 10

Pesticide	
Pesticide type	Atrazine (1.41 kg/ha)
Pesticide Application Date	May 2

The study was conducted in two sub-watersheds in the Black Creek watershed in Allen County, Indiana. The Smith-Fry and Driesbach watersheds are 942 ha (2327.7 acres) and 714 ha (1764.3 acres) in size, respectively, and they eventually drain into Lake Erie. The fields in Smith-Fry and Driesbach were digitalized on high resolution maps using Arc GIS software (Figure 5). Corn and soybean fields were extracted by overlaying field boundaries on NASS and NLCD layers. For Smith-Fry, 105 fields were extracted from the 163 digitized fields. The field soil units were extracted by masking the soil layer to each field. The percentage of each soil unit was calculated using the python programming language.

Field simulation

For each soil unit, simulation was performed for a 32-year period with the specified model inputs. The model has been calibrated and validated for locations throughout Indiana and has been found to perform satisfactorily in previous studies. Since comparisons were made only with simulated data, the model did not require additional calibration and validation work. Thus, the simulations were directly done.

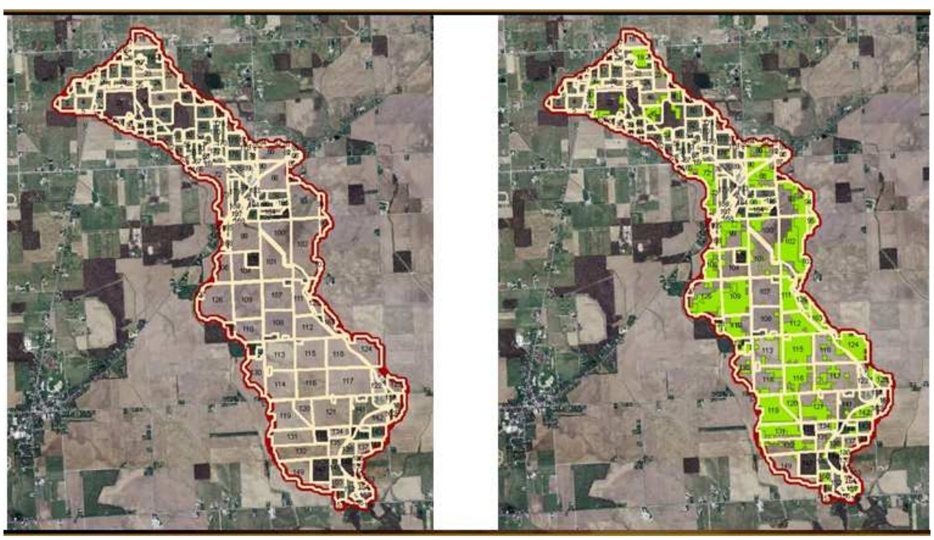

Figure 5: Digitization of field on high resolution map and overlaying on NASS layer

To calculate the pesticide and nutrient loss for each field, each soil in the watersheds (SSURGO and STATSGO) was simulated using Web NAPRA. Based on the percentage of the soil unit, weighted averages of model outputs were computed to simulate the pollutant loss by generating the probability of excedence for nitrogen, pesticide and phosphorus for each field. To increase the spatial extent of areas considered, the permutation of fields in its proximity were area weighted averaged for each STATSGO soil type (IN004,IN003, IN116) to calculate the pollutant loss at the edge of the field.

Result:

The Kolmogorov-Smirnov test (KS-test) was used to determine if simulated SSURGO and STATSGO pesticide and nutrient losses were similar by increasing the spatial resolution at field scale simulation using the NAPRA tool. It was observed that by increasing the spatial resolution too, the data did not show significant similarity. The pollutant losses for STATSGO soil data were at the higher or lower end compared to SSURGO soil data results. So by increasing the spatial extent, the data sets were more dissimilar. There is high variation in the erodability factor among different components in a soil type causing the difference (figure 7). The soil type and slope affects the runoff and percolation in both SSURGO and STATSGO. The K-S test comparison cumulative fraction plot for annual erosion, annual runoff and annual percolation show a higher D value and p value is almost equal to 0. SSURGO field simulations are done with respect to a particular STATSGO soil, the standard deviation of STATSGO is almost 0. Erosion estimates varied between soils and is influenced by soil texture, slope-length and tillage system. The D value for erosion for two fields, in the location of STATSGO soil type IN004 is a cumulative percentile of 1, which shows that SSURGO and STATSGO based erosion estimates are different in the area of IN004 STATSGO soil type. With the increase in the size of the fields, the results were not similar as expected. The same was for IN003 STATSGO soil type location. Soil type, IN116 showed a convergence in the erosion estimates (D=0.63), but still IN116 soil type, erosion estimate is significantly different. Runoff estimates were also significantly different for the locations in the three soil types with D>0.7 for the area of four fields. The percolation estimates for the location in IN004 and IN003 soil type showed D between 0.9 to 1.0. IN116 soil type location had D lower than 0.5 but was not consistent with the increase in the size of the field. The graphical representation is for Smith Fry fields and corn soybean rotation (Figure 6, 7, and 8).

Evaluate current and future agricultural management practices common near the Great Lakes on phosphorus loads.

Cropping systems, such as corn-soybean rotations, can serve to protect the environment and maintain the economic viability of producers. In the model simulations, two cropping management systems were considered, continuous corn and corn-soybean rotation. Cropping management input data such as planting date, harvest date, maturity date, method of fertilizer application, fertilizer type and tillage method are the same for both scenarios. Planting, harvesting and maturity dates are based on data obtained from Indiana Agricultural Statistics Reports. Based on the two cropping patterns, the simulations are done using NAPRA to identify the phosphorus load for each field for Smith-Fry and Driesbach subwatersheds. Total phosphorus is the sum of the 50% annual probability of exceedence for phosphorus loading to runoff, leached and sediment transport.

Corn-stover is considered one of the best-suited biofeedstocks for bioenergy production based on regional transportation and economic analyses. Due do the focus on biofeedstock production, there is a need to quantify the environmental effects due to the increase in biofeedstock production. The environmental effect due to phosphorus loss due to increase in biofeedstock production can be assessed using the NAPRA model. The same inputs were given to the corn stover simulation with the additional parameters for surface crop residue parameters and the USLE C factor for stover removal. The model is used to simulate a hypothetical increase in the biofeedstock use, three corn stover removal scenarios were incorporated, baling a windrow (38%); raking and baling (52.5%); and shredding, raking and baling (70%). Based on environmental impacts, decision makers can control or increase the biofeedstock production in a location.

In a corn-soybean rotation, erosion increased with the amount of stover removed (figure 12, 16) as expected. However, the phosphorus level in runoff (figure 9, 13) and sediment (figure 11, 15) decreased with increase in the amount of stover removed and showed a slight increase in the 72% stover removal, since in the simulation the phosphorus in the stover was not replaced in the form of additional fertilizer. Future simulations will consider addition of phosphorus fertilizer to replace that removed with the stover. Although estimated erosion and phosphorus values varied across corn stover removal rates for both the rotation, there was no significant difference in mean annual estimated erosion losses with ($p < 0.05$).

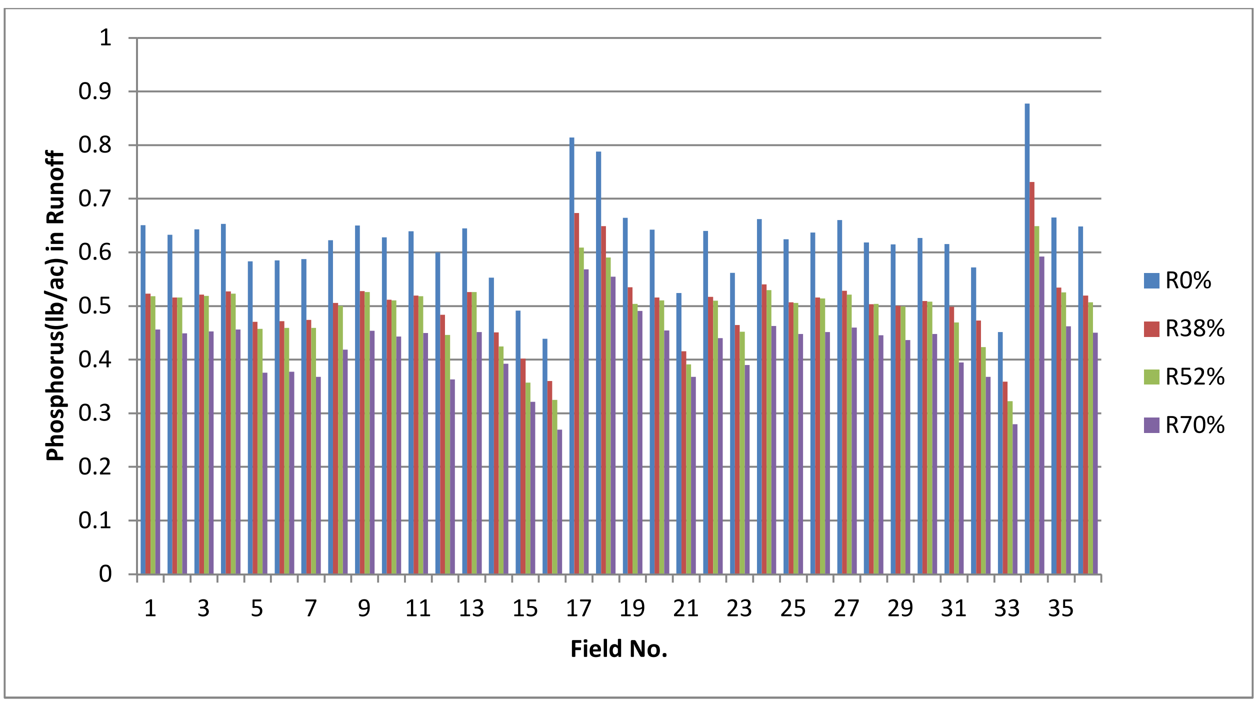

Figure 9 Phosphorus in runoff with three corn stover removal rates under corn-soybean rotation (R0: no residue removal; R38: 38% removal; R52: 52.5% removal; R70%: 70% removal)

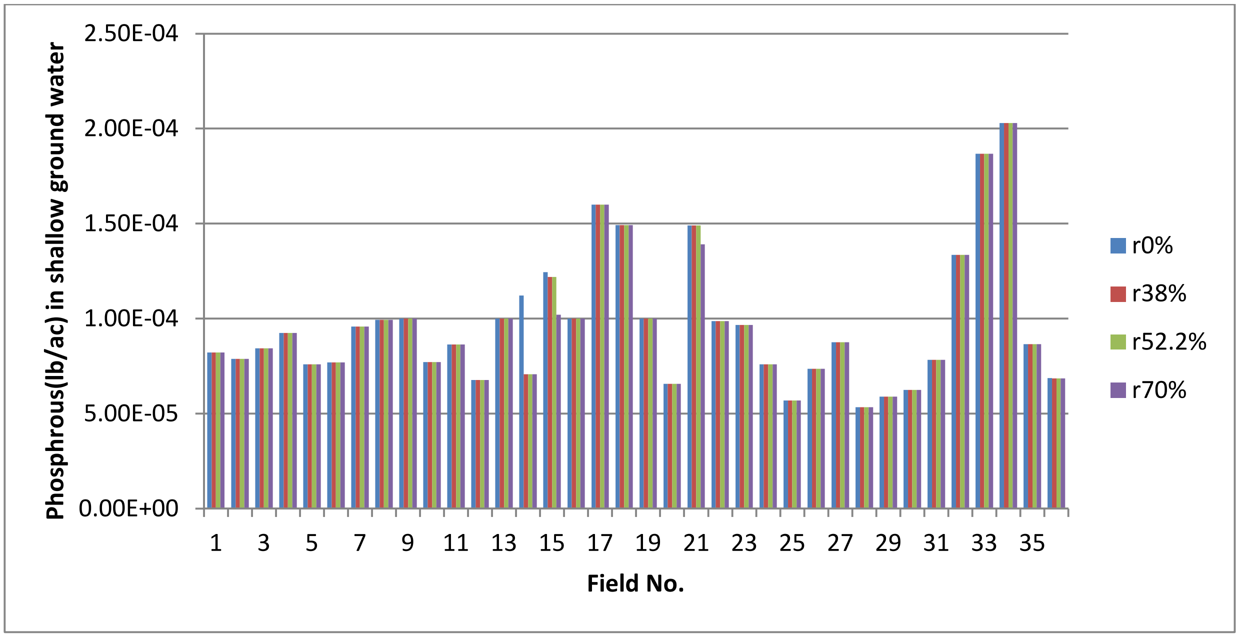

Figure 10 Phosphorus in shallow groundwater with three corn stover removal rates under corn-soybean rotation (R0: no residue removal; R38: 38% removal; R52: 52.5% removal; R70%: 70% removal).

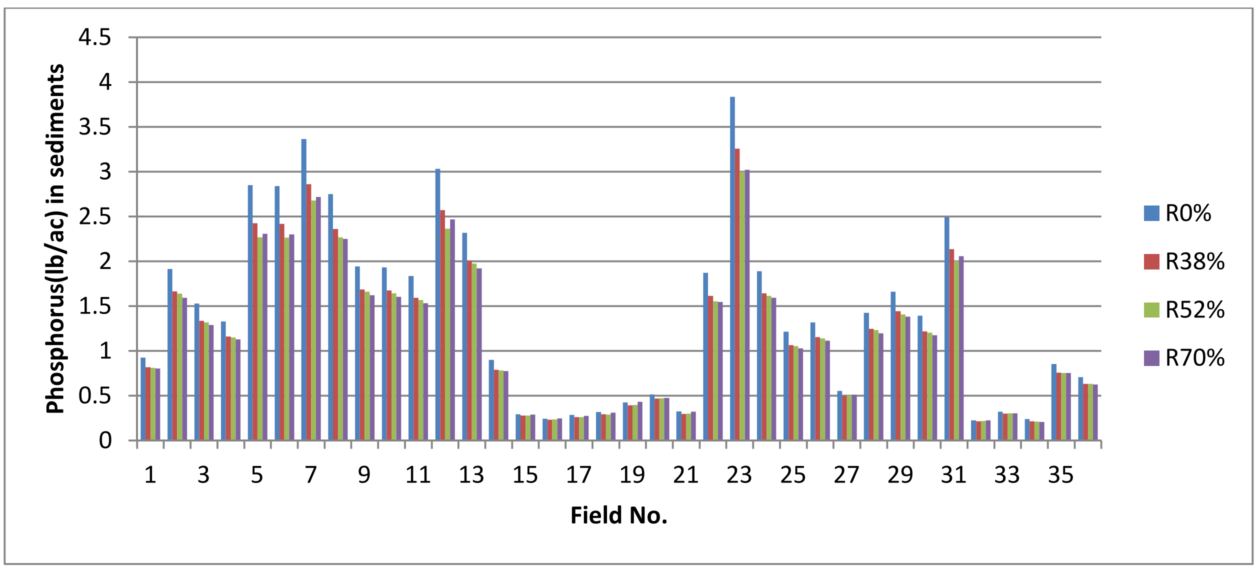

Figure 11 Phosphorus in sediments with three corn stover removal rates under corn-soybean rotation (R0: no residue removal; R38: 38% removal; R52: 52.5% removal; R70%: 70% removal).

.

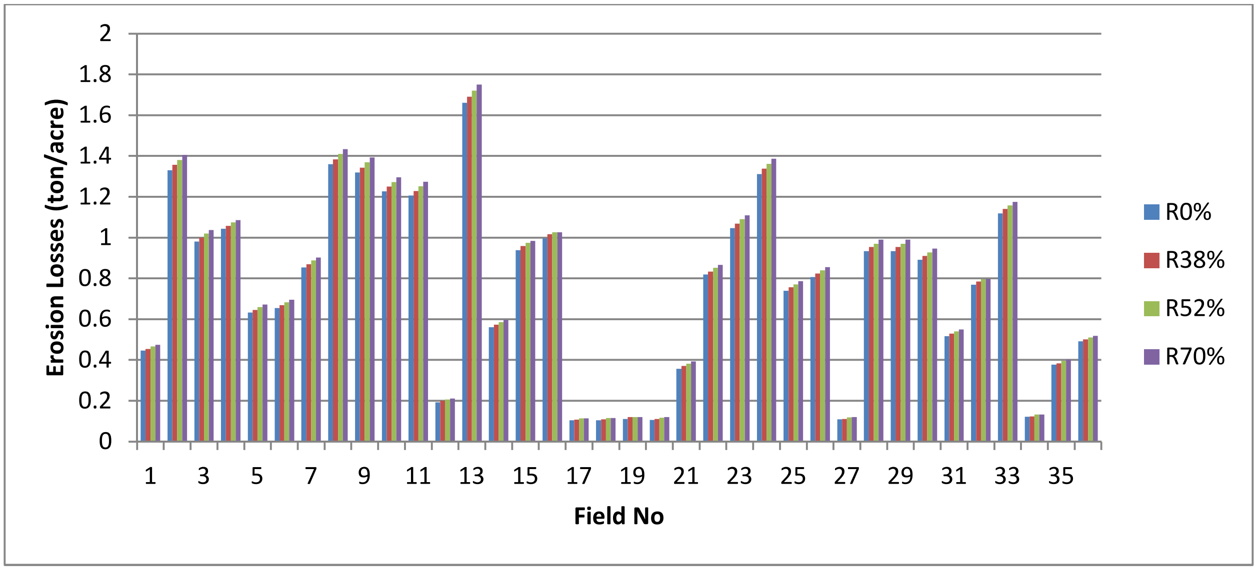

Figure 12: Annual erosion losses associated with three corn stover removal rates for corn-soybean rotation (R0: no residue removal; R38: 38% removal; R52: 52.5% removal; R70%: 70% removal).

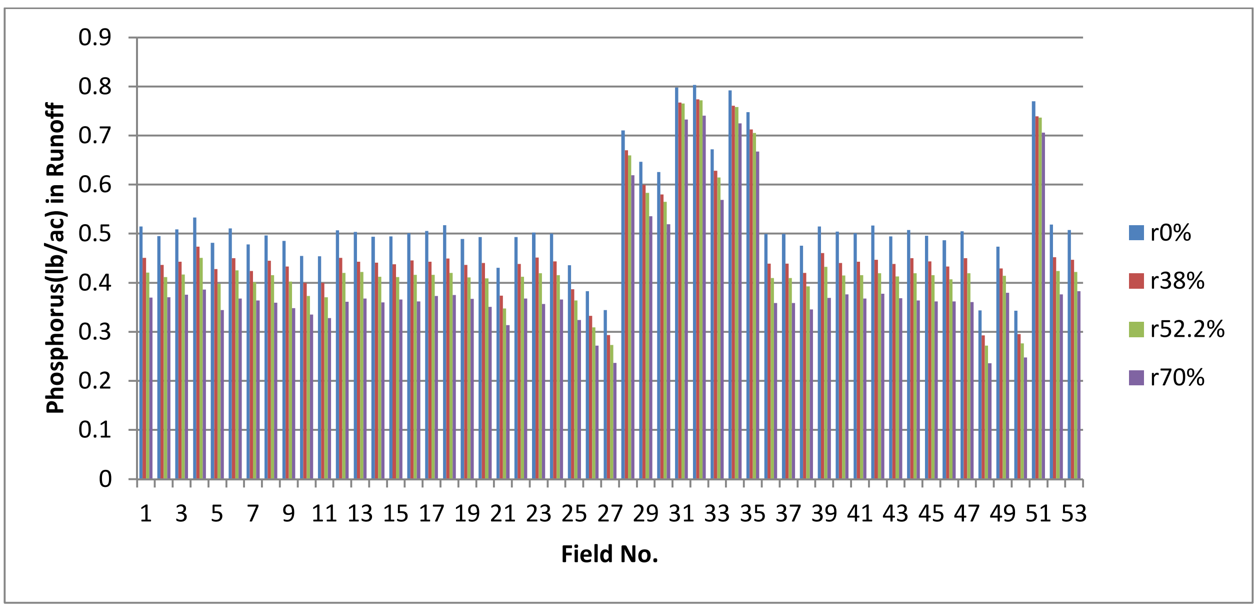

Figure 13 Phosphorus in runoff with three corn stover removal rates for soybean-corn rotation (R0: no residue removal; R38:38% removal; R52: 52.5% removal; R70%: 70% removal).

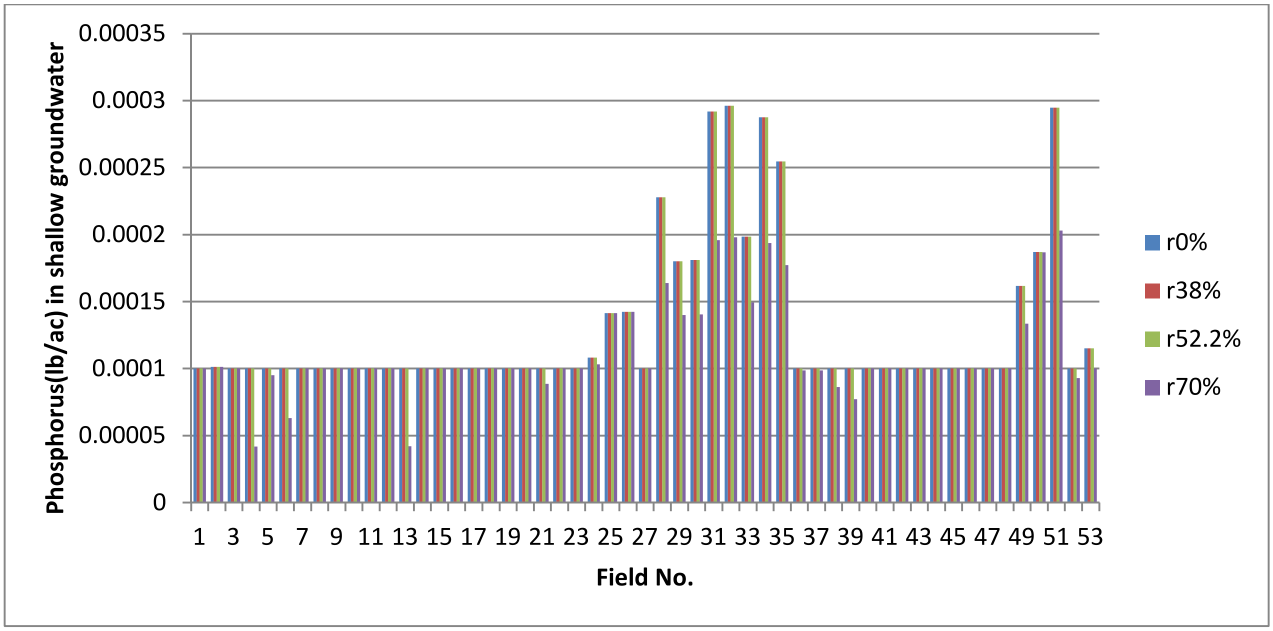

Figure 14 Phosphorus in shallow groundwater with three corn stover removal rates under soybean-corn rotation (R0: no residue removal; R38: 38% removal; R52: 52.5% removal; R70%: 70% removal).

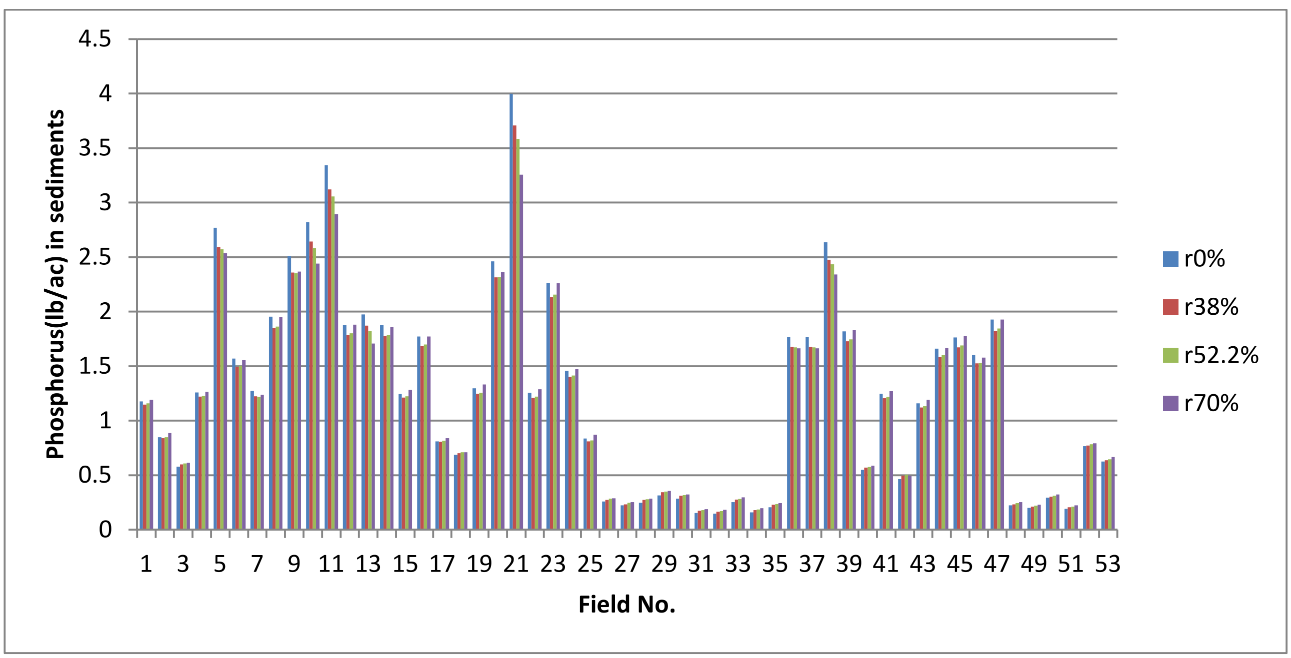

Figure 15: Phosphorus in sediments with three corn stover removal rates under soybean-corn rotation (R0: no residue removal; R38: 38% removal; R52: 52.5% removal; R70%: 70% removal).

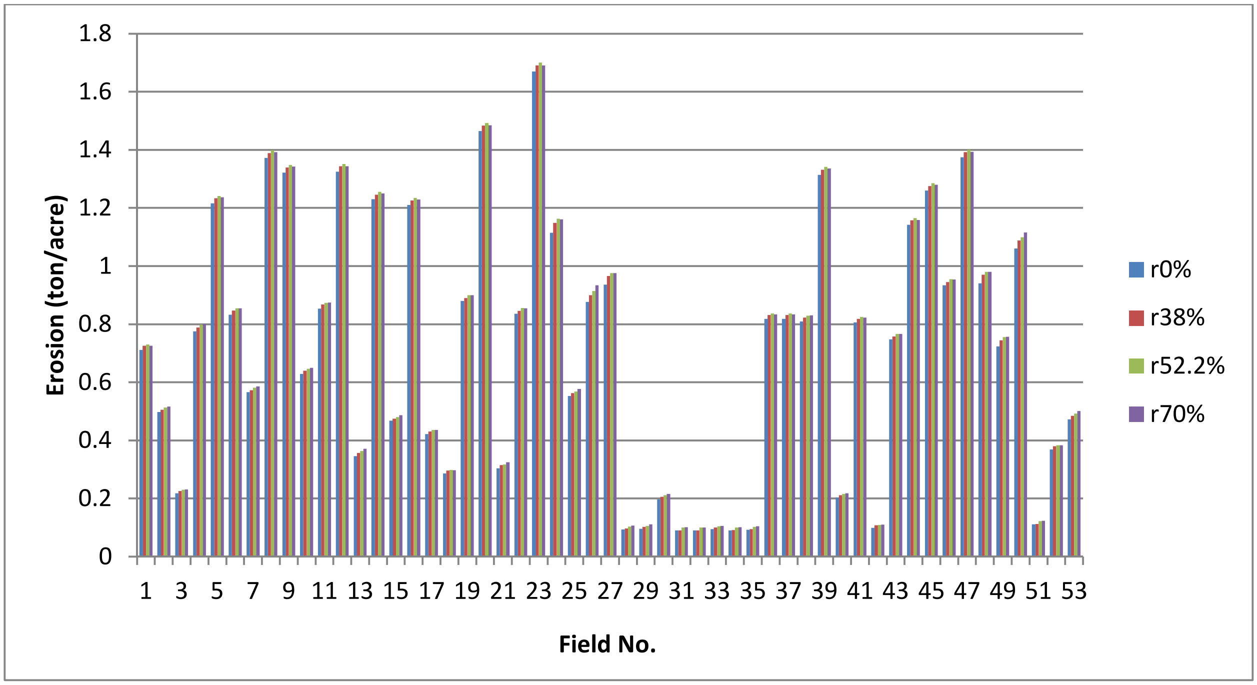

Figure 16: Annual erosion losses associated with three corn stover removal rates under soybean-corn rotation (R0: no residue removal; R38: 38% removal; R52: 52.5% removal; R70%: 70% removal).

Training and Evaluation of the tool:

NAPRA web was initially tested and evaluated for improvement by future stakeholder. It was observed that the users on average found the tool user-friendly and useful. The comments and suggestions were very informative. Steps were taken to incorporate the major changes required. Training was conducted for the students on the tool. A workshop is scheduled for planners and stakeholders..

Presentations and Publications

- Training/ Workshops
  - Acushla Antony presented a paper on" Web- Based Decision Support Tool to Forecast Nutrient Losses from Agricultural Watersheds". ASABE Annual International Meeting, Pittsburg, June20-24, 2010

  - Acushla Antony, Presented a paper on ”Web-Based Decision Support Tool for Nutrient and Pesticide Analysis” in the 2009 ASABE Annual International Meeting on June 21 – June 24, 2009, Grand Sierra Resort and Casino, Reno, Nevada.
- Publication
  - Acushla Antony, Bernard Engel (2009). **“**Web-Based Decision Support Tool for Nutrient and Pesticide Analysis” for ASABE Annual International Meeting ASABE Paper No. 096994, St. Joseph, Mich.: ASABE .

- Guest Lecture

    1. A guest lecture for ASM 336 on 22nd Nov, 2010 on the topic "Web based National Agricultural Pesticide Risk Analysis (NAPRA) tool".

    2. A guest lecture for ABE 591 on 7th April, 2011 on the topic "Web based National Agricultural Pesticide Risk Analysis (NAPRA) tool".

Funds utilization:

Funds from this grant supported expendable supplies and equipment for use in this project. And also supported to attending professional meeting to present results and conduct training on the developed tool.

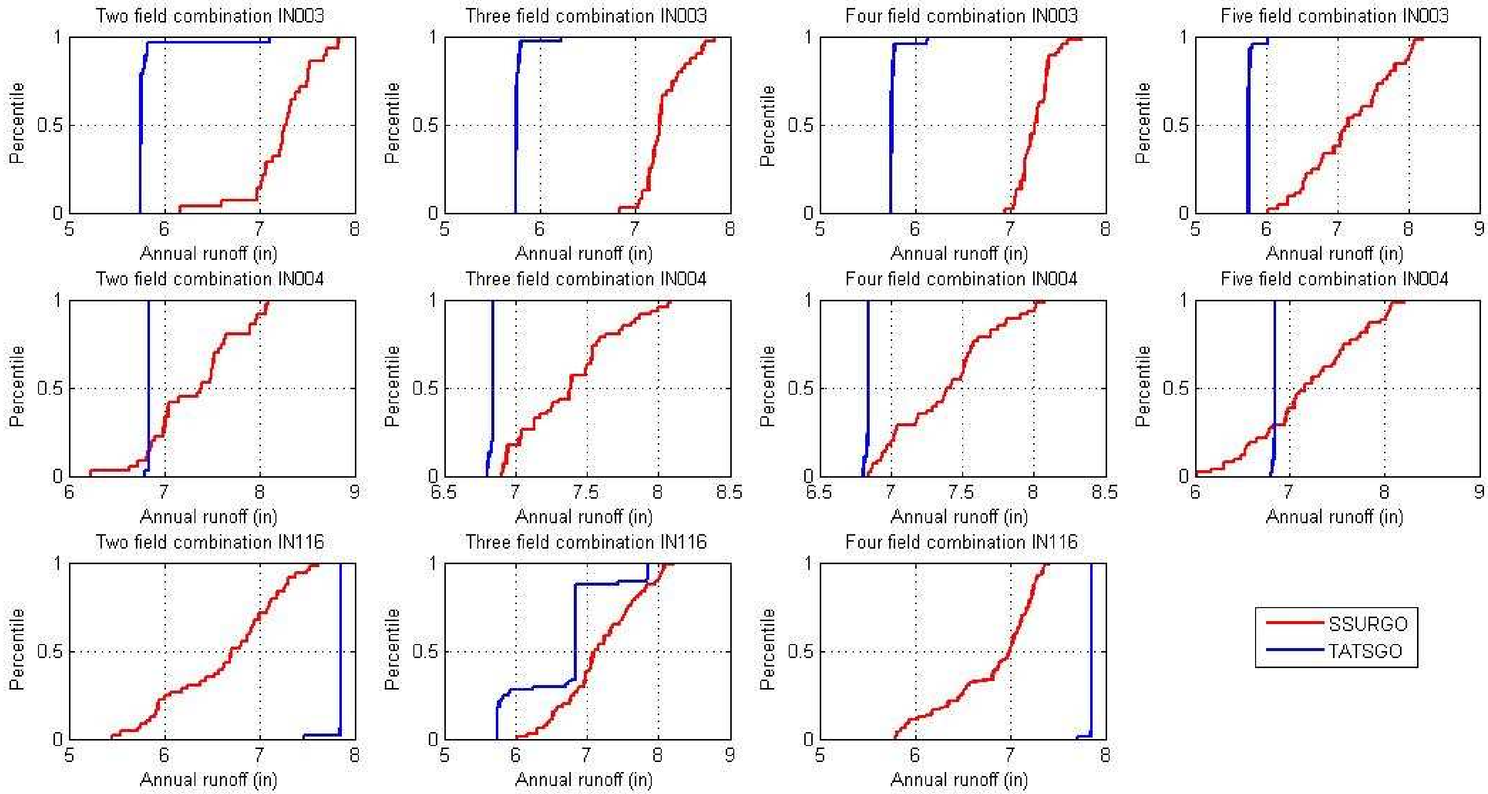

Figure 6: K-S test comparison cumulative fraction Plot for Annual Runoff

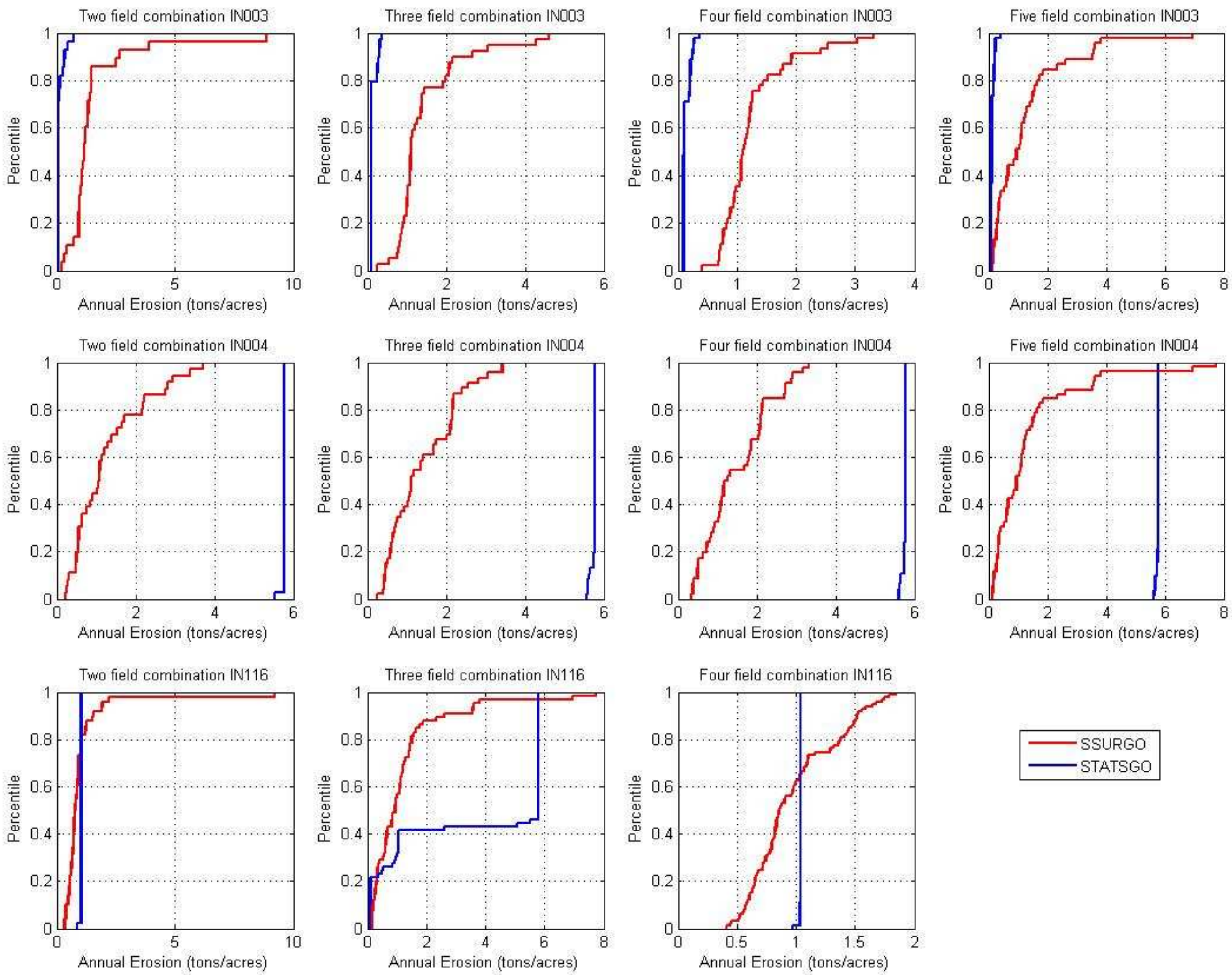

Figure 7: K-S test comparison cumulative fraction Plot for Annual Erosion

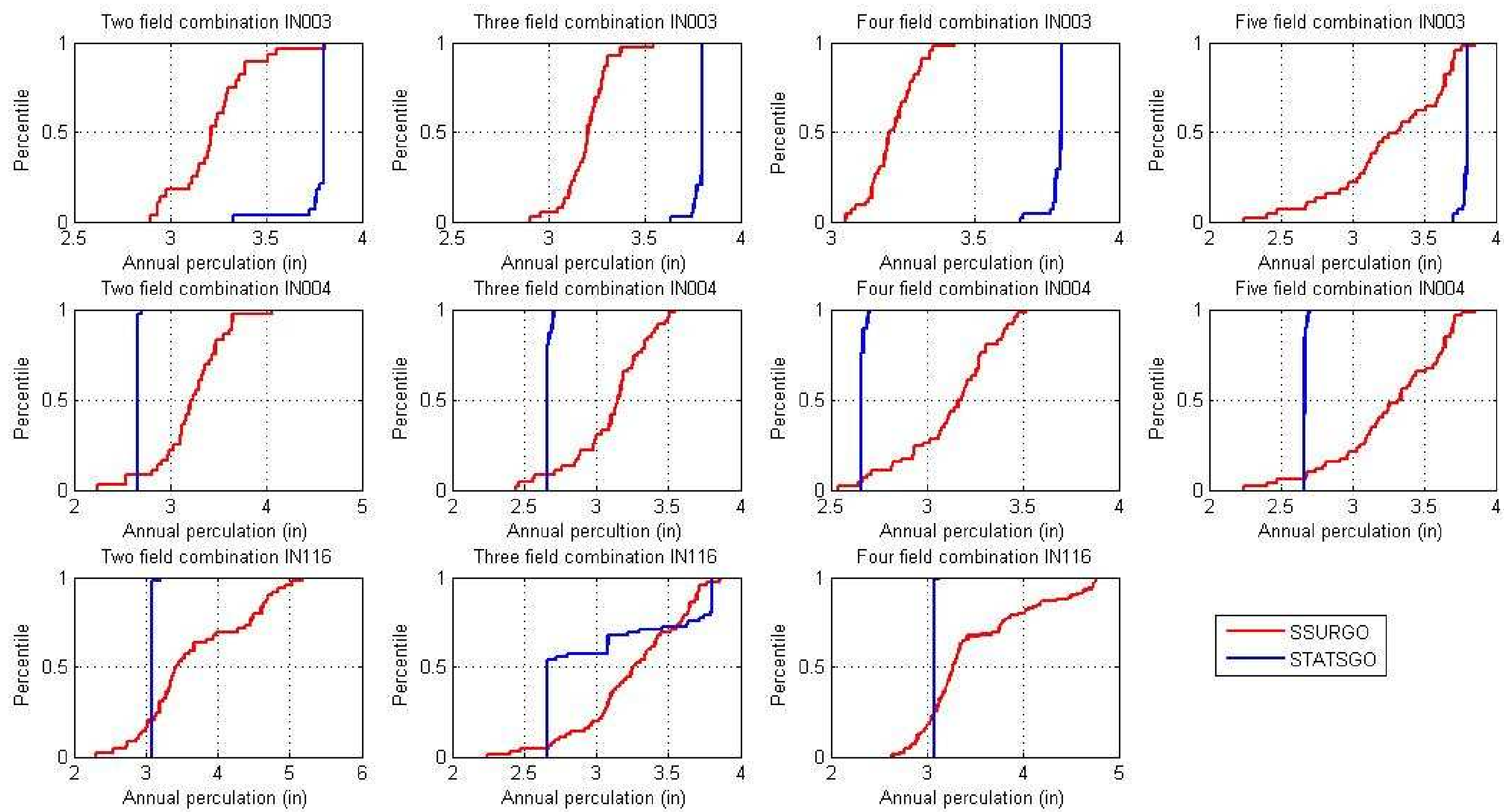

Figure 8: K-S test comparison cumulative fraction Plot for Annual Percolation